Arsenic and Landfills: Protecting Water Quality

Arsenic Sources and Assessment

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Natural Arsenic Bearing Solids

- **Natural Arsenic Bearing Solids**
  - Minerals
    - Arsenopyrite (Iron Arsenic Sulfide)
    - Scorodite (Hydrated Iron Arsenate)
    - Realgar (Arsenic Sulfide)
    - Orpiment (Arsenic Sulfide)
  - Mining Waste
  - Mineral Processing waste

Arsenic Bearing Solid Wastes to be Disposed in Landfills

- **Common arsenic bearing wastes**
  - Arsenic bearing solid residuals (ABSRs) from drinking water treatment facilities
  - CCA treated wood and Construction and demolition debris
  - Wallboards (made from FGD materials – reuse of CCPs)
  - Industrial solid waste

ABSR Quantities In Landfills

- **Drinking Water Residuals - Solids**
  - Iron based media – GFH/GFO
  - Activated Alumina – AA
  - Titanium dioxide
- **Projected Amount**
  - With a reduction in As MCL, about 6 -24 million lbs of ABSRs will be generated annually which will contain 24, 000 lbs of As.

Type of ABSR	Concentration mg/Kg
GFH	up to 45000 (46 % water content)
AA	1270 (46 % water content)
GFO	5660 (50 % water content)
MAA	443 (32 % water content)
TiO_2	3554 (50 % water content)

Source: Final Report on the "Disposal of Arsenic-Bearing Water Treatment Residuals: Assessing the Potential for Environmental Contamination" Workshop Rio Rico, Arizona, 2006

CCA Treated Wood Quantities in Landfills

- **CCA Treated Wood**
  - Usually has an arsenic content of 16-45 %.
- **Projected Amount**
  - Year 2006
    - Florida - 13.7 x 10^6 ft^3
    - USA – 171.2 x 10^6 ft^3
  - Year 2016
    - Florida – 31.0 x 10^6 ft^3
    - USA – 397.3 x 10^6 ft^3

Types of Wood	Mean Concentration (Range) mg/Kg
Unburned other wood	2.0 (0.26-7.2)
Unburned CCA	1200 (290-2050)
Ash other wood	67 (7.5-79.7)
Ash CCA	33000 (8980-45000)

Source: Generation, use, disposal, and management options for CCA-treated wood, 1998, Florida Center for Solid and Hazardous Waste Management (Helena Solo-Gabriele, Tim Townsend)

Other Arsenic Burden in Landfills

- **Wallboards and FGD materials**
  - Disposal in C& D landfills only.
  - Some FGD products contain arsenic.
- **Projected Amount**
  - 100 million tons of CCPs generated annually with over 50 % of these disposed in landfills.
  - Over 25 million tons of FGD material produced with 9% used annually in wallboard manufacture and will eventually end up in C& D landfills.

Type	Mean Concentration (Range) mg/Kg
Wallboard (Source: PA)	3.50 (2.65-4.0)
Dry FGD (Source: PA)	4.98 (0.90-8.58)
Wet FGD (Source: IL)	3.67
Fly Ash (Coal)	111.86

Sources: In-house research study; USEPA document and EPRI issued report

Various Disposal Scenarios

- **The disposal of the arsenic sources or wastes varies with the type.**
  - Municipal solid waste (MSW) landfills – drinking water residuals are disposed in these landfills. Disposal of arsenic bearing solid residuals (ABSRs) from drinking water plants in Construction and Demolition (C&D) landfills is currently prohibited under RCRA
  - C & D landfills – accepts construction and demolition debris including wallboards, CCA treated wood
  - Industrial waste landfills – accepts industrial wastes
  - Hazardous solid waste landfills – accepts hazardous wastes
  - Mining and Mineral Processing Wastes – disposed in monofills

Potential Problems with Landfill Disposal

- Groundwater contamination due to arsenic leaching
- Impact on leachate quality
- Long-term operational issues
- The TCLP test, used to estimate contaminant release, may not accurately predict arsenic leaching from some wastes in landfills
- The characteristics of each arsenic source is different and behaves differently under each disposal scenario

Estimating Arsenic Release from Solid Wastes

- Under RCRA guidelines, the current approach for the risk assessment of solid wastes is via batch leaching tests
  - Acidic solutions (TCLP, SPLP, WET etc.)
    - TCLP – for MSW disposal
    - SPLP – For land application
    - WET – Waste assessment test used in California
  - 20:1 Liquid to solid ratio and 18 hours contact time
- Other non-regulatory test include:
  - Constant pH tests (Kosson et al, 2002; Bishop et al, 2004; EPA/ORD)
  - Landfill leachate test
  - Bench/Pilot Scale Column Tests

Common Issues with Estimation of Arsenic Release

- TCLP and other leaching tests predict leaching under only one set of conditions, they cannot however accurately predict waste leaching over a full range of environmental conditions known to occur in disposal sites and landfills.
- Solubility, desorption, and volatilization of different metals varies with pH and many other factors. Leaching tests performed at a single pH value will either over- or under-predict actual leaching of contaminants from a disposal site or a landfill.
- The characteristics of the waste, speciation of arsenic and other environmental and geochemical factors are not accounted for in any one leaching tests.

How Does Arsenic Behave In Landfills?

- Studies have shown that arsenic behavior in landfills is dependent on variety of factors.
  - An increase in one unit of pH may increase the fraction of arsenic leached by 3-4 times;
  - Presence of natural organic matter (NOM) and phosphate displace arsenic from the sorbent sites up to three magnitudes higher than sulfate or silicate;
  - Mature landfill simulation column studies show that iron sorbents undergo reductive dissolution, leading a delayed spike in arsenic leaching;
  - Mobilization of arsenic, specifically As (V), can occur via its microbial mediated reduction to As (III).

What Are the Estimation Tools in Use to Determine Arsenic Leaching?

- Batch Leaching Tests
  - TCLP
  - SPLP
  - Landfill leachate Tests
- Short-term constant pH tests
- Controlled redox tests
- Bench/ pilot column tests (variable L/S)
- Full scale field verification tests
- Generic Empirical and Mechanistic models (Kinetics and Equilibrium)

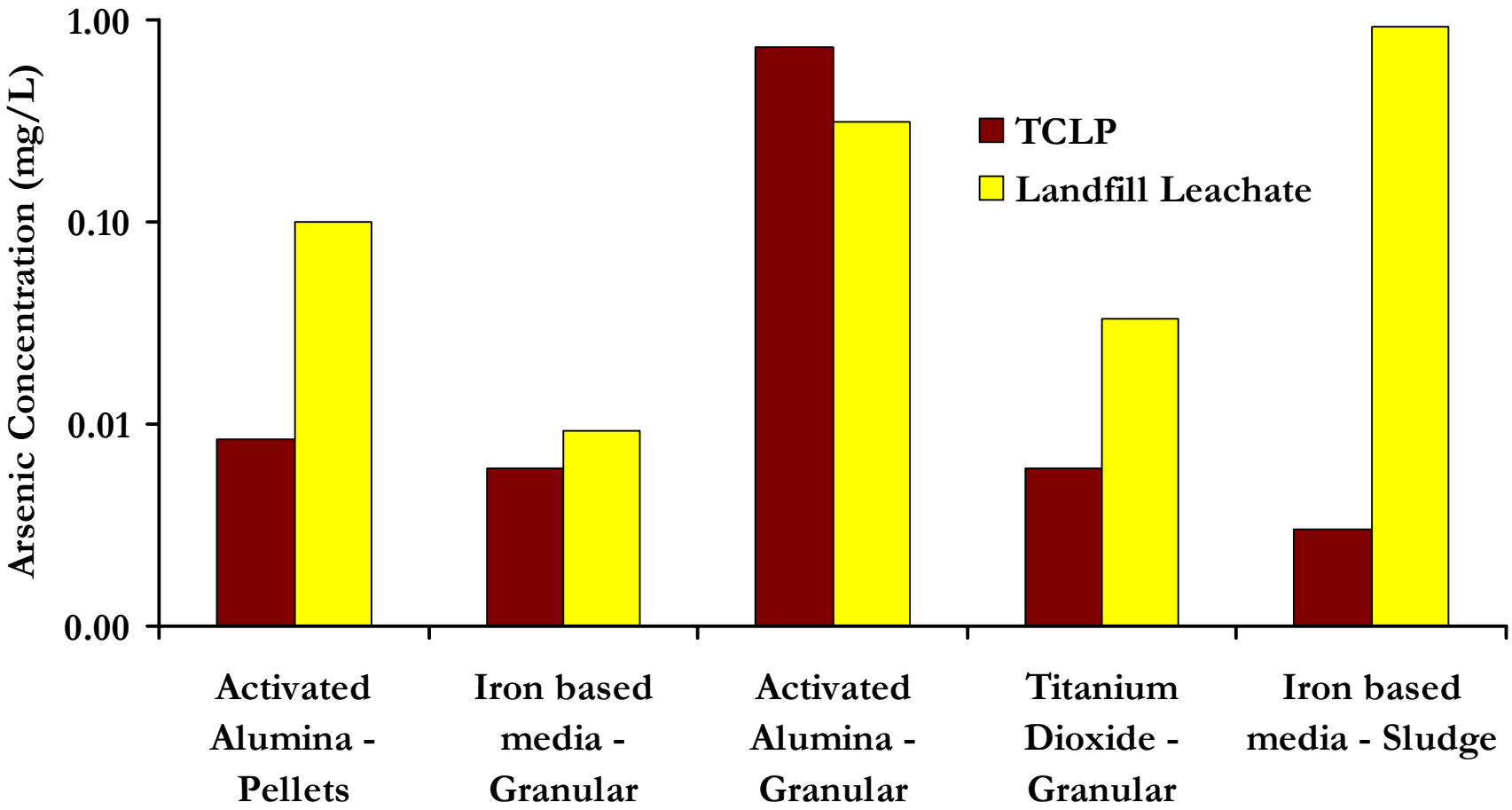
Do the Tests Accurately Predict Arsenic Leaching?

- Under RCRA guidelines, the toxicity of ABSRs is determined by the TCLP test:
  - Most treatment residuals passed the TCLP test. The leachate concentration was less than the TC limit of 5 mg/L.
- However, in comparison to the landfill leachate tests, it was observed that the TCLP under-predicts arsenic leaching
  - The characteristics of the extraction fluid such as pH, organic content, presence of anions influence the leaching of arsenic
  - The type of ABSR, whether activated alumina or iron based media determine extent of arsenic release.
  - Short –term leaching studies may not be an accurate predictor of arsenic mobilization in landfills.

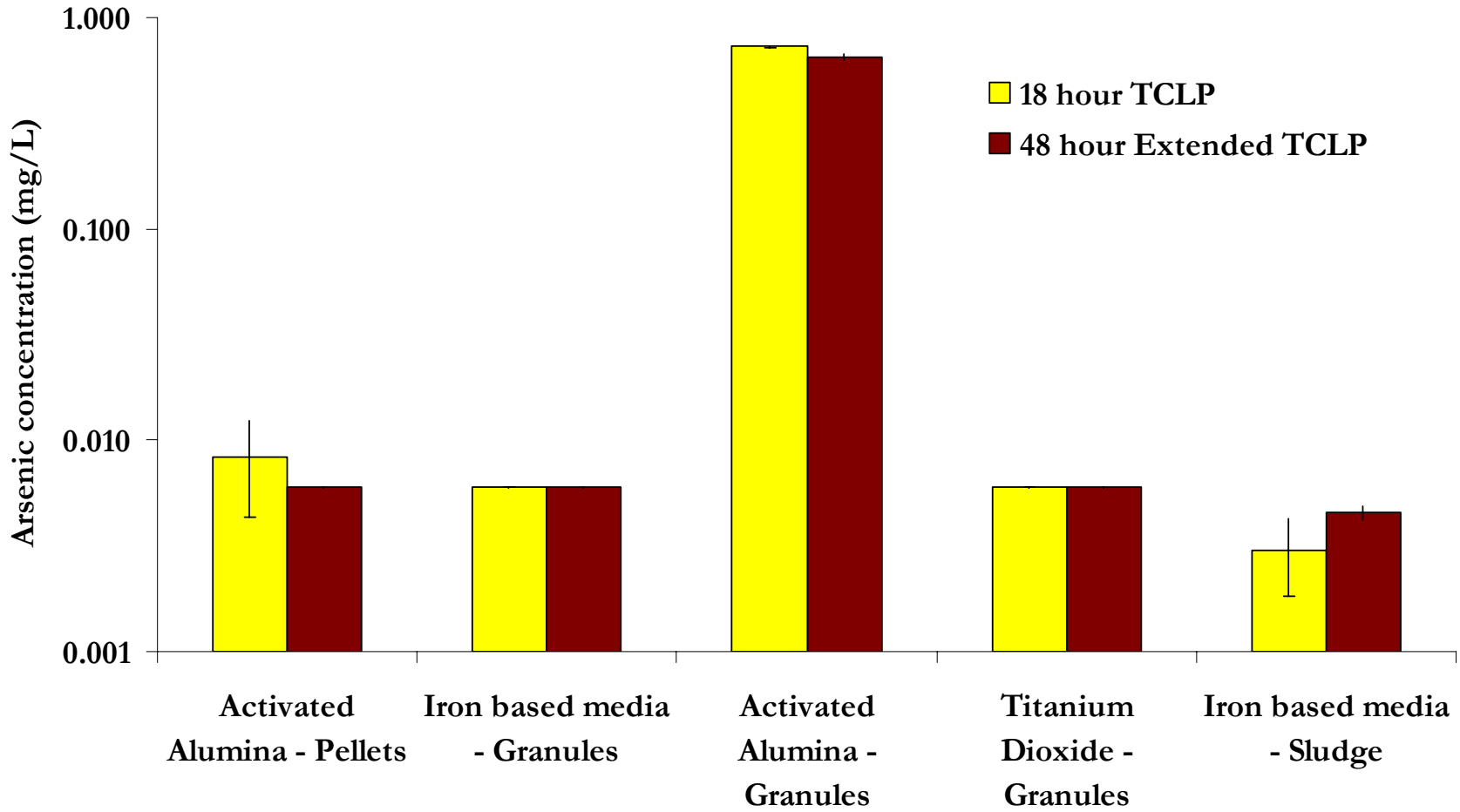
Parameters Needed To Be Tested

- The important parameters that needs to be tested are:
  - Arsenic content in ABSRs (threshold values)
  - Type of adsorbent media
  - Arsenic speciation in the solid (it is known that desorption of As (III) species from the solid is higher that the As (V) species)
  - pH and redox
  - Microbial effect on arsenic reduction in landfills
  - Comparison of regulatory tests (TCLP, SPLP and WET) with each parameter.

Comparison of TCLP vs. Landfill Leachate

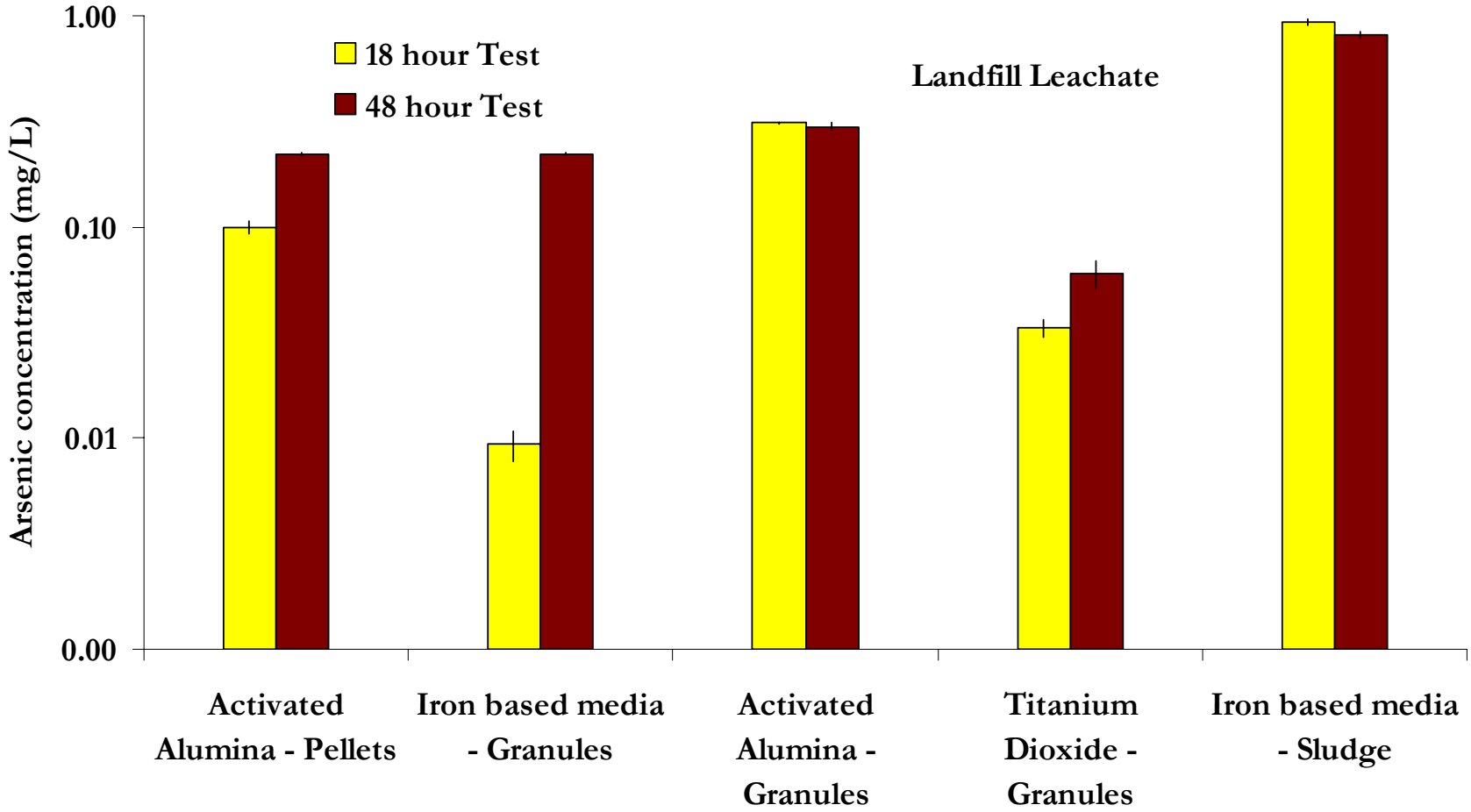


Effect of Test Duration (TCLP)

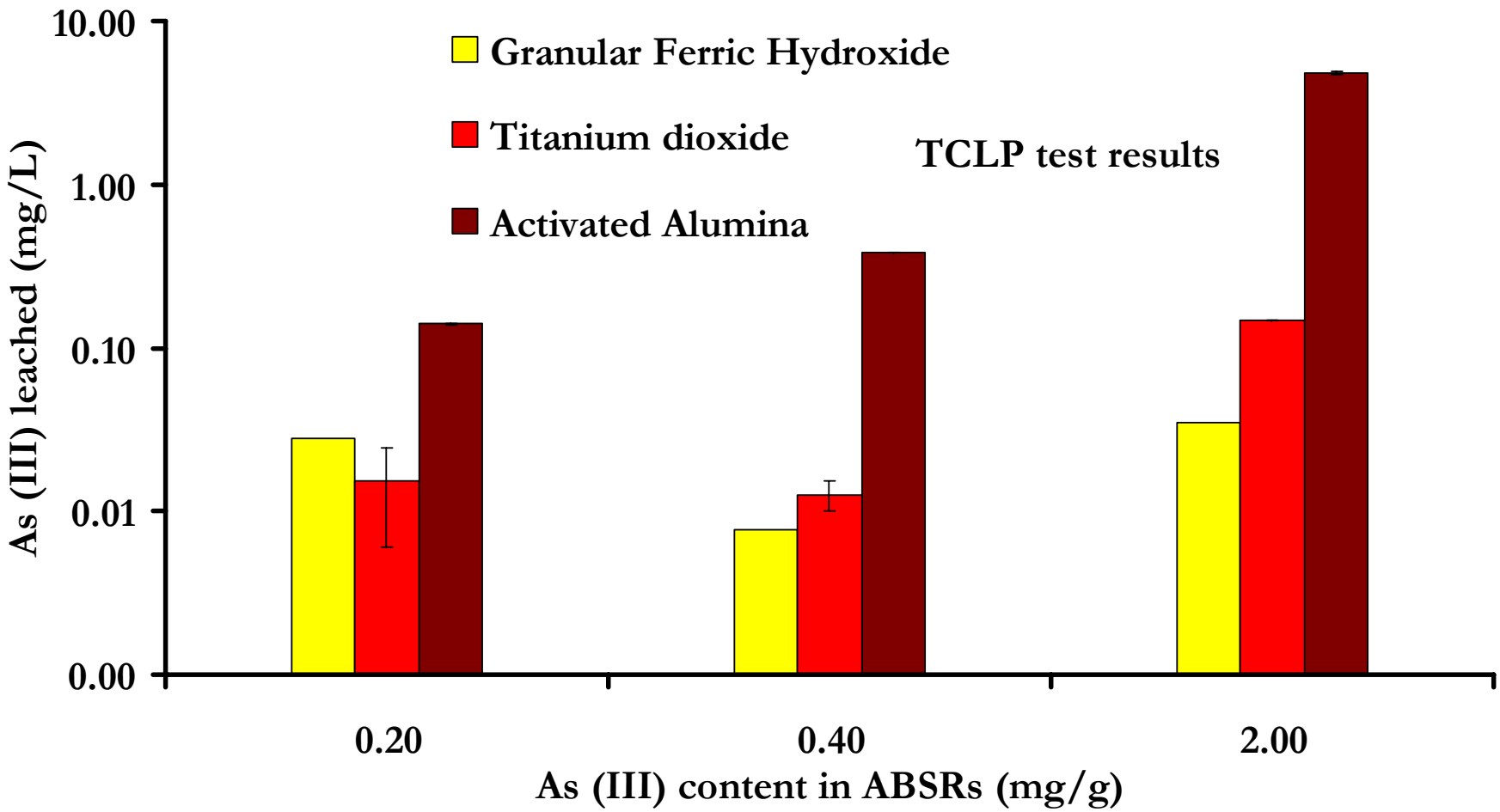


No significant difference observed in the extended test.

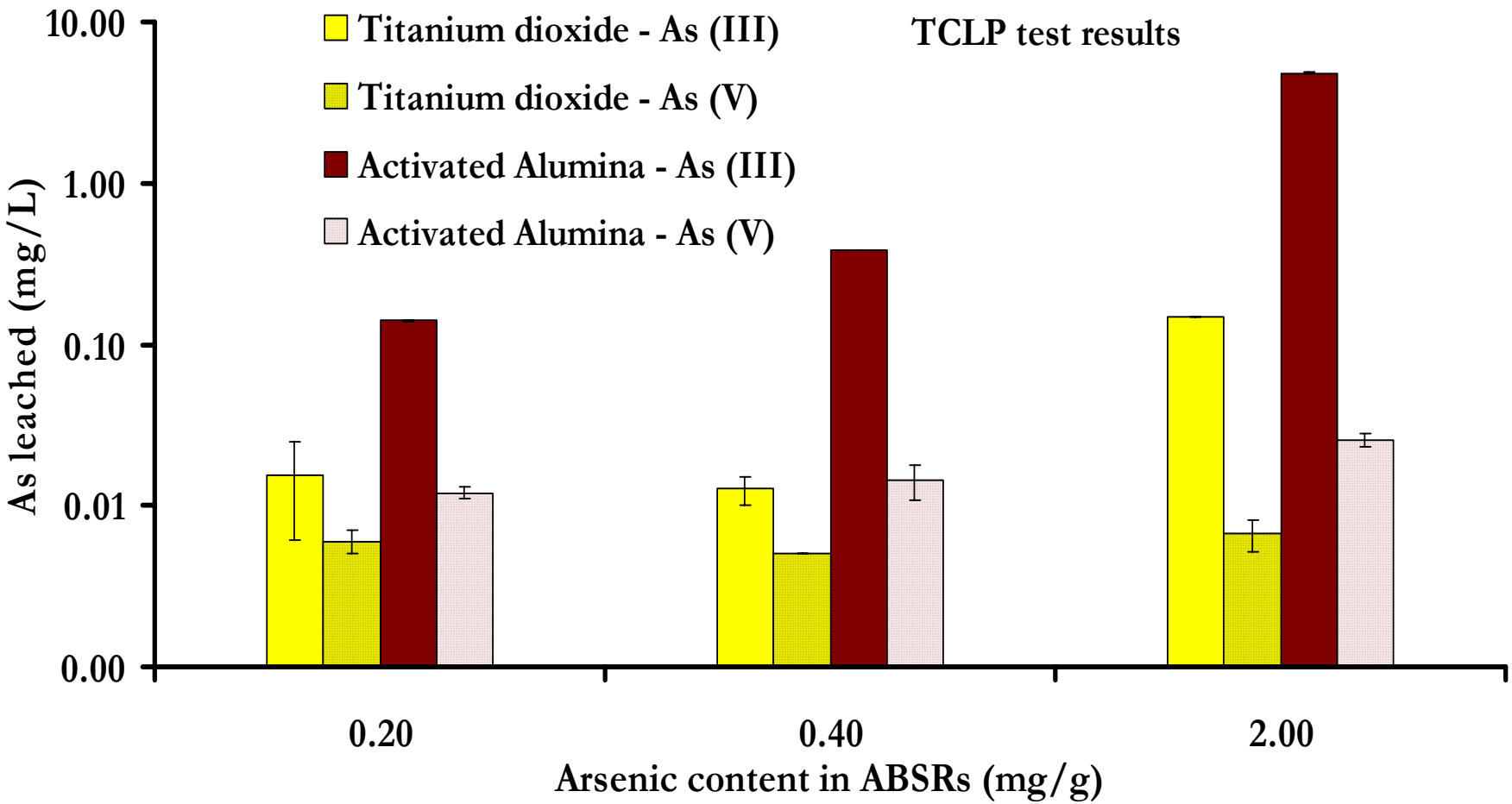
Effect of Test Duration (Landfill Leachate)



Effect of Arsenic Content and ABSR Type



Effect of Arsenic Species in ABSRs



What if the wastes Were Different

Waste derived fertilizer

Metal (mg/L)	DI	SPLP	TCLP	LL
As	39.9 ± 0.5	39.8 ± 1.1	0.9 ± 0.04	0.14

Mineral Processing Waste

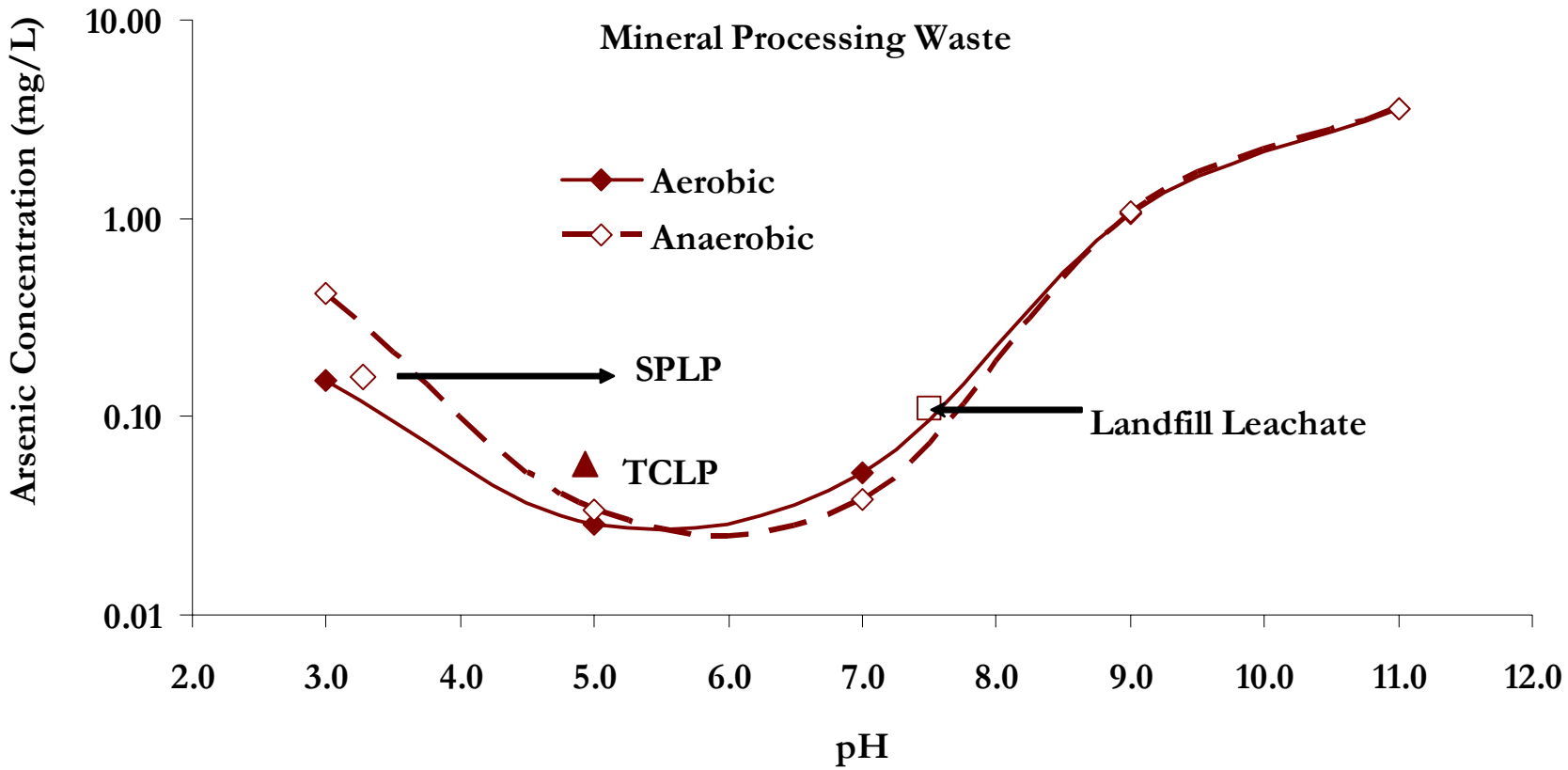
Metal (mg/L)	DI	SPLP	TCLP	LL
As	0.05 ± 0.00	0.2 ± 0.02	0.06 ± 0.00	0.17

Granular Ferric Hydroxide - ABSR

Metal (mg/L)	DI	SPLP	TCLP	LL
As	<MDL	<MDL	0.01 ± 0.00	0.03 ± 0.00

LL: Landfill Leachate Tests; DI: Deionized water tests

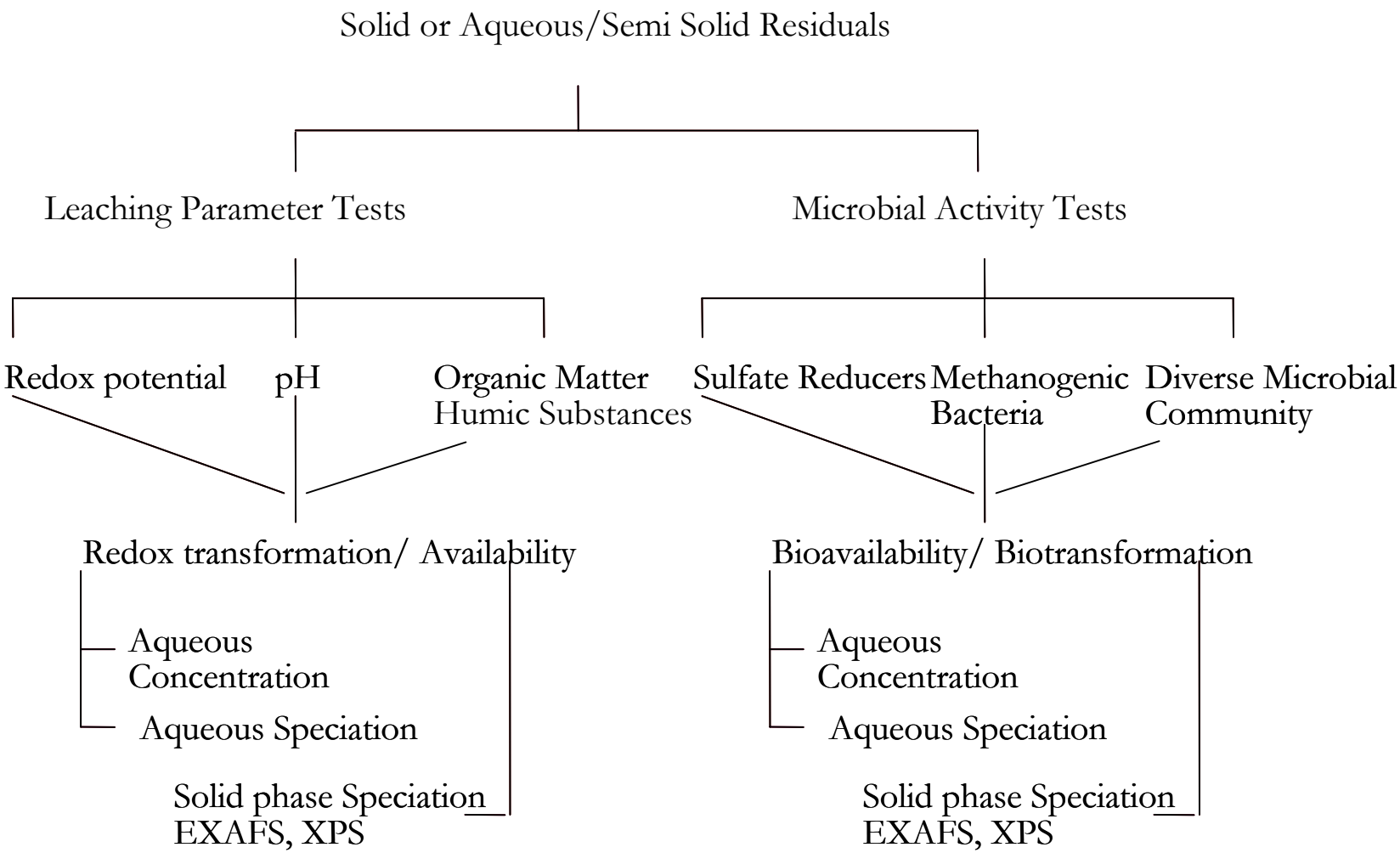
What If the pH varies



What we Know So Far About ABSRs and Other Wastes

- Higher arsenic content resulted in higher leaching
- Activated alumina is more likely to release arsenic, compared to titanium dioxide or iron based media (GFH)
- As (III) is more likely to be readily mobilized from the solid ABSRs as compared to As (V)
- Arsenic leaching is higher at high and low pH
- Redox conditions may affect arsenic release when iron media is present
- The characteristics of the waste determines the behavior of arsenic release

Proposed Approach – What Should We do



What are the Research Questions that need to be Addressed regarding Arsenic bearing waste?

- Do we have enough information to determine a safe disposal of the arsenic bearing wastes, and their treatment alternatives?
- Do different arsenic wastes show similar leaching characteristics? What is the effect of physiochemical and biological variables such as pH, microbial activity, redox and organic matter on arsenic leaching?
- What alternate leaching protocols needs to be devised for more accurate prediction of arsenic leaching?

Specific Questions Related to ABSRs

- Under what conditions is the disposal of ABSRs in MSW hazardous to the environment or the public's health? Is there any threshold value for the arsenic content in the ABSRs so as to enable their long-term stability?
- If the disposal of ABSRs in MSW is a problem, would it be appropriate to dispose them in C & D landfills (which is not a legal disposal option)?
- If yes, then should the arsenic content in other wastes (CCA treated wood and wallboards) be taken into account to predict cross-media transfer and leaching?

Questions?